

AFRL-SN-WP-TP-2005-114

**NARROWBAND MID-INFRARED
GENERATION IN ELLIPTICALLY
PUMPED PERIODICALLY POLED
LITHIUM NIOBATE**



Peter E. Powers, Prasanth K. Bojja, Eric Vershure, and Kenneth L. Schepler

FEBRUARY 2003

Approved for public release; distribution is unlimited.

STINFO INTERIM REPORT

© 2002 Optical Society of America

This joint work is copyrighted. One of the authors is a U.S. Government employee working within the scope of his position; therefore, the U.S. Government is joint owner of the work and has the right to copy, distribute, and use the work. Any other form of use is subject to copyright restrictions.

**SENSORS DIRECTORATE
AIR FORCE RESEARCH LABORATORY
AIR FORCE MATERIEL COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OH 45433-7320**

NOTICE

Using Government drawings, specifications, or other data included in this document for any purpose other than Government procurement does not in any way obligate the U.S. Government. The fact that the Government formulated or supplied the drawings, specifications, or other data does not license the holder or any other person or corporation; or convey any rights or permission to manufacture, use, or sell any patented invention that may relate to them.

This report is releasable to the National Technical Information Service (NTIS). It will be available to the general public, including foreign nationals.

PA Case Number: Not applicable—already in the public domain.

THIS TECHNICAL REPORT IS APPROVED FOR PUBLICATION.

/s/

Kenneth L. Schepler
Principal Scientist
EOCM Technology Branch

/s/

William R. Taylor, Acting Chief
EOCM Technology Branch
EO Sensors Technology Division

/s/

ROBERT D. GAUDET, Colonel, USAF
Chief, EO Sensor Technology Division
Sensors Directorate

This report is published in the interest of scientific and technical information exchange and its publication does not constitute the Government's approval or disapproval of its ideas or findings.

| REPORT DOCUMENTATION PAGE | | | | | Form Approved OMB No. 0704-0188 | |
|--|-----------------------------|--|---------------------------------------|--|---|--|
| <p>The public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.</p> | | | | | | |
| 1. REPORT DATE (DD-MM-YY) February 2003 | | 2. REPORT TYPE Conference Paper Postprint | | 3. DATES COVERED (From - To) 03/01/2002 – 11/01/2002 | | |
| 4. TITLE AND SUBTITLE NARROWBAND MID-INFRARED GENERATION IN ELLIPTICALLY PUMPED PERIODICALLY POLED LITHIUM NIOBATE | | | | 5a. CONTRACT NUMBER In-house | | |
| | | | | 5b. GRANT NUMBER | | |
| | | | | 5c. PROGRAM ELEMENT NUMBER 61102F | | |
| 6. AUTHOR(S) Peter E. Powers, Prasanth K. Bojja, Eric Vershure (University of Dayton) Kenneth L. Schepler (AFRL/SNJW) | | | | 5d. PROJECT NUMBER 2301 | | |
| | | | | 5e. TASK NUMBER EL | | |
| | | | | 5f. WORK UNIT NUMBER 01 | | |
| 7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) University of Dayton Center for Electro Optics 300 College Park Dayton, OH 45469-2314 | | | | 8. PERFORMING ORGANIZATION REPORT NUMBER AFRL-SN-WP-TP-2005-114 | | |
| 9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) Sensors Directorate Air Force Research Laboratory Air Force Materiel Command Wright-Patterson AFB, OH 45433-7320 | | | | 10. SPONSORING/MONITORING AGENCY ACRONYM(S) AFRL/SNJW | | |
| | | | | 11. SPONSORING/MONITORING AGENCY REPORT NUMBER(S) AFRL-SN-WP-TP-2005-114 | | |
| 12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution is unlimited. | | | | | | |
| 13. SUPPLEMENTARY NOTES © 2002 Optical Society of America. This joint work is copyrighted. One of the authors is a U.S. Government employee working within the scope of his position; therefore, the U.S. Government is joint owner of the work and has the right to copy, distribute, and use the work. Any other form of use is subject to copyright restrictions. Published in CLEO (Conference on Lasers and Electro-Optics) Summaries, 2003, Optical Society of America. | | | | | | |
| 14. ABSTRACT Narrow bandwidths and near diffraction limited beam divergence are demonstrated in an elliptically pumped, diode-laser seeded, optical parametric generator. This represents a significant step towards high-energy tunable infrared systems with favorable beam characteristics. | | | | | | |
| 15. SUBJECT TERMS Laser, infrared, narrow bandwidth, optical parametric generator, periodically poled lithium niobate | | | | | | |
| 16. SECURITY CLASSIFICATION OF: | | | 17. LIMITATION OF ABSTRACT: SAR | 18. NUMBER OF PAGES 8 | 19a. NAME OF RESPONSIBLE PERSON (Monitor) Kenneth L. Schepler 19b. TELEPHONE NUMBER (Include Area Code) (937) 904-9661 | |
| a. REPORT Unclassified | b. ABSTRACT Unclassified | c. THIS PAGE Unclassified | | | | |

Narrowband mid-infrared generation in elliptically pumped periodically poled lithium niobate

Peter E. Powers, Prasanth K. Bojja, and Eric M. Vershure

Center for Electro Optics, University of Dayton, 300 College Park, Dayton OH 45469-2314
peter.powers@notes.udayton.edu

Kenneth L. Schepler

Air Force Research Laboratory, AFRL/SNJW, Bldg 622, WPAFB OH 45433-7706

Abstract: Narrow bandwidths and near diffraction limited beam divergence are demonstrated in an elliptically pumped, diode-laser seeded, optical parametric generator. This represents a significant step towards high-energy tunable infrared systems with favorable beam characteristics.

© 2002 Optical Society of America

OCIS codes: (190.4360) Nonlinear optics, devices

We report on a method to control both the bandwidth and the divergence of elliptically-pumped optical parametric generation devices (OPG's) using a diode laser seeding scheme. This source has important applications such as in environmental sensing where propagating a beam over long distances is required, and where narrow bandwidth is required for chemical species selectivity. Previous work with high-energy OPG's has shown that elliptical pumping is a viable means of scaling up the energy of OPG devices [1]. However, the use of large aperture pump beams increases the size of the gain channel in the material for a given OPG interaction. This, in turn, allows multiple noncollinear processes to see gain throughout the length of the material in addition to collinear processes. To mitigate these effects, periodically poled lithium niobate (PPLN) crystals were poled with several separated gratings that had the effect of limiting the noncollinear interactions. Even so, the collinear bandwidth for such devices is still large and the beam divergence is that of a single one of the gratings. In the present work we use a diode laser co-aligned with the pump laser to act as a spectral and spatial seed. The favorable narrowband and diffraction-limited beam properties of the seed beam are shown to be transferred to the OPG output.

To demonstrate this experimentally the pump beam was supplied by a Q-switched Nd:YAG laser operating at 10 Hz with 3.5-ns pulses. The operating wavelength was 1.064 μm and the energy was 6 mJ. The laser beam profile was a "top hat," and this was relay imaged onto a 30-cm focal length cylindrical lens. The cylindrical lens focused the laser into a 3.2 mm x 200 μm (diameter) cross section. The pump beam was aligned through a 29.75- μm periodicity PPLN crystal. The PPLN aperture was 5 mm x 0.5 mm, and its length was 30 mm. A cw-diode laser was co-aligned with the pump to have a slightly larger ellipticity to ensure overlap with the pump. The power of the cw diode laser was varied up to 9 mW incident on the crystal.

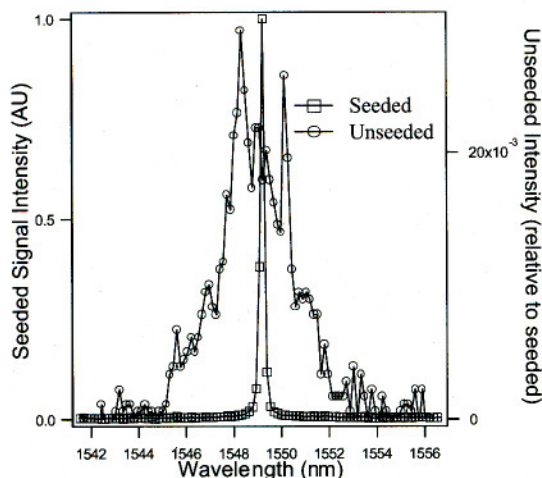


Fig. 1. Seeded and unseeded output of elliptically pumped OPG. Note unseeded intensity references the right ordinate axis and is much lower in intensity than the seeded bandwidth.

Figure 1 shows the output signal bandwidth of the OPG with and without seeding. It is clear from the figure that seeding significantly reduced the bandwidth. The bandwidth is less than 1 cm^{-1} , limited by the resolution of the monochromator. The energy in the signal and idler beams was measured to be 0.7 mJ when pumping with 8 mJ, and seeding with 9 mW. The threshold for effective seeding was 0.5 mW incident on the crystal. The far-field beam profile of the idler when seeded and unseeded was measured with an infrared camera, and is shown in figure 2. Figure 2 (a) shows that the beam divergence is nearly equal in the vertical and horizontal directions for the unseeded idler. This indicates that the beam is far from diffraction limited and can be attributed to multiple noncollinear processes that see significant gain. Because of the elliptical beam shape in the crystal, a diffraction-limited beam would be highly asymmetric in the far field. A diffraction-limited beam should have a large divergence in the vertical direction where the elliptical beam is small and it should have a small divergence in the other direction. Figure 2 (b) shows that when the signal beam is seeded, the idler takes on the expected beam shape in the far field of a diffraction limited beam. Note that two distinct beams can easily be seen. The crystal, AR coated for the pump and signal, was not AR coated for the idler. This gives rise to an etalon effect, and coupled with a slightly wedged crystal gives rise to multiple idler outputs. The divergence of the idler when seeded is 1.9 mrad (FWHM) in the narrow direction, which is 1.5 times diffraction limited. This, when compared to the 29-mrad divergence of the idler when not seeded shows a great improvement in beam quality.

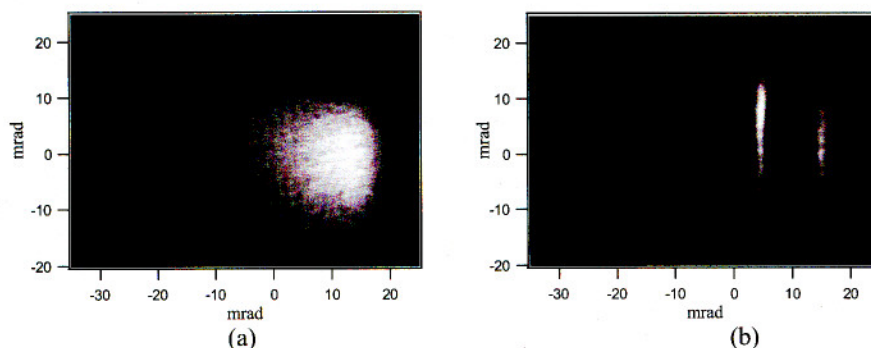


Fig. 2. Far-field profile of the idler: a) unseeded b) seeded. Note that the seeded profile required higher attenuation in front of the camera to avoid saturation.

In conclusion, we demonstrate a viable path to generating high-energy and narrow-bandwidth in the mid-IR with a simple system. This will have an impact on laser remote sensing applications that require high energy and good beam characteristics.

- 1 S. M. Russell, P. E. Powers, M. J. Missey, K. L. Schepler, "Broadband mid-infrared generation with two-dimensional quasi-phase-matched structures," *IEEE Journal of Quantum Electronics* 37,877-887 (2001).